CERES CLOUD PRODUCTS

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CERES Cloud Activities & Plans

- Complete Terra Ed2 and Aqua Ed1 through 2007
  - *Deal with Collection 4 and 5 differences*
  - *GEOS-4 to end December 2007*
- Examine impacts of changes from GEOS-4 to MERRA
- Refine & test changes for Edition 3
  - *Use CALIPSO-CloudSat & GLAS data*
  - *Field program & surface site data*
- Prepare & submit papers on algorithms, validation, & calibration

CALIBRATION

- Paper submitted to JTECH on visible channel calibrations

  Used: 1) MODIS-A vs MODIS-T vs VIRS

  2) MODIS vs CERES SW

  3) DCC albedo

=>

- VIRS V6 needs a 1%/y gain correction
- Terra needs a 1.17% discontinuity correction in Nov 2003
- Aqua seems to be stable, confirms FM4 degradation
- Terra 1% less than Aqua, Ed3 needs to decide which is reference & adjust one or the other

VALIDATION

- Paper submitted to JGR on stratus val at ARM SGP
  - height underestimated by 300- 500 m
    - soundings would give larger overestimate w/ larger RMS
  - Terra re, tau, and LWP very close on average
  - Aqua re within 0.3 μm on average
    tau & LWP large by 7 & 25%

=>

- -5.5°/km lapse rate would yield unbiased heights, same RMS
- adjust Aqua VIS channel?

Collection 4 vs Collection 5 (Terra)

- Select 8 days of data from different seasons
  - *Examine differences in each channel as function of*
    SZA, VZA, RAZ, scan angle, temperature (reflectance)
  - *Examine differences in derived properties for 4 & 5*

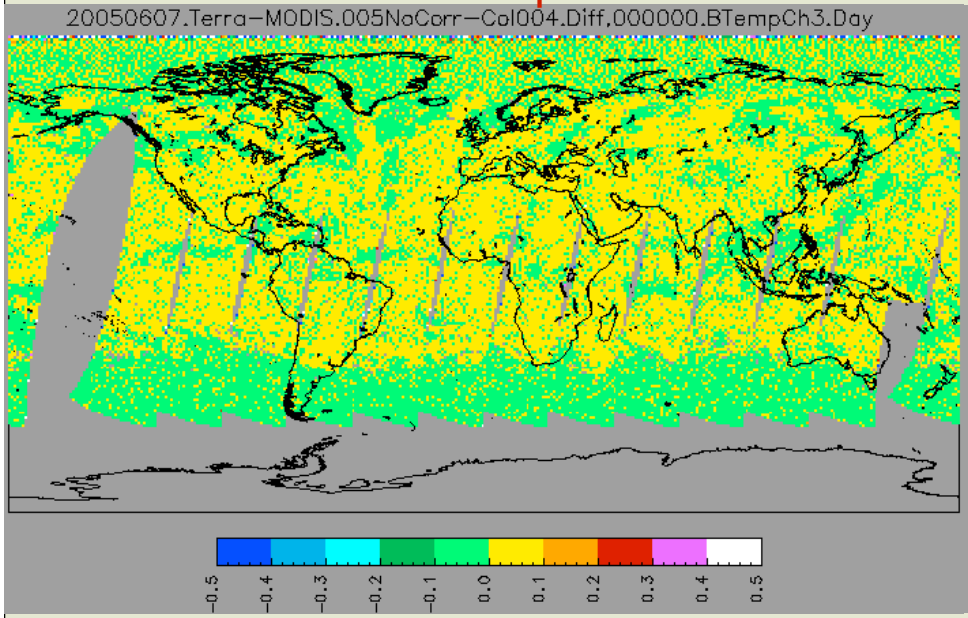
=>

- No discernable predictable changes in reflectance/temperature for any channel
  - some dependence on scan & reflectance angle for visible, but no common pattern

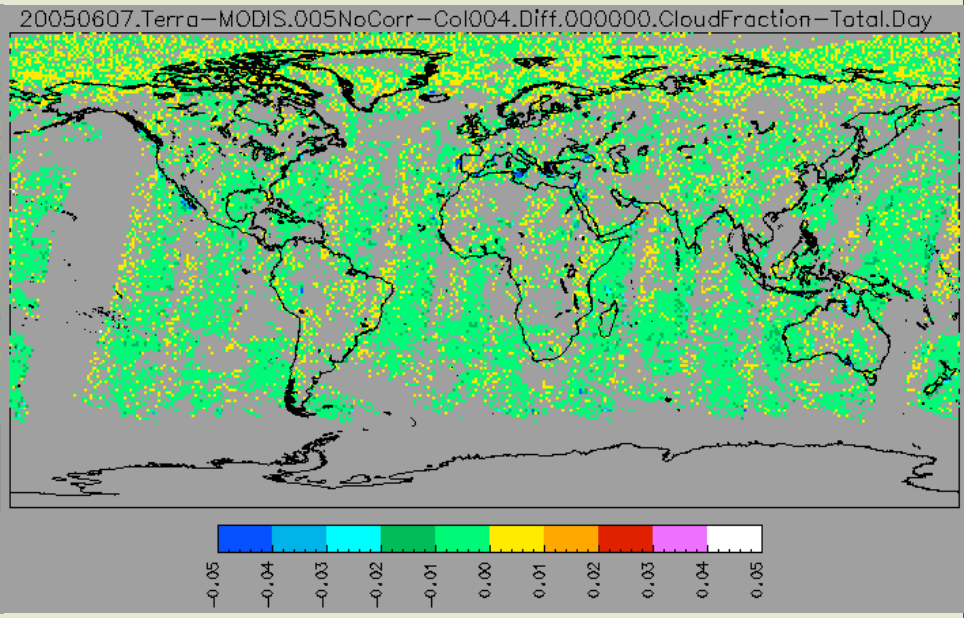
- Differences in cloud fraction vary with day, time of day

Impact of Collection 5 on Cloud Fraction 6/7/2005

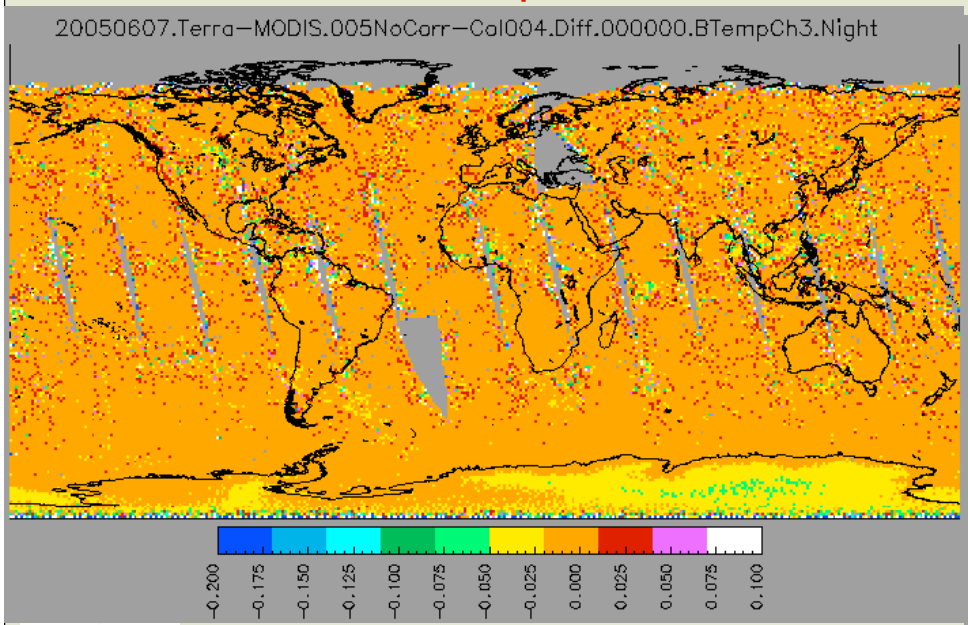
Ch 3 Temp Diff DAY



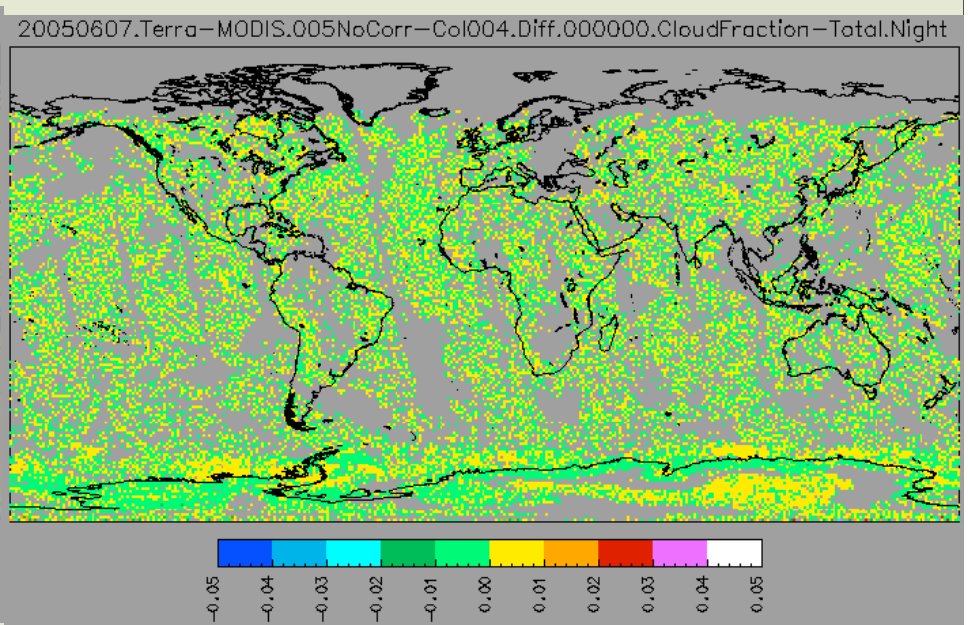
Cloud fraction



Ch 3 Temp Diff NIGHT

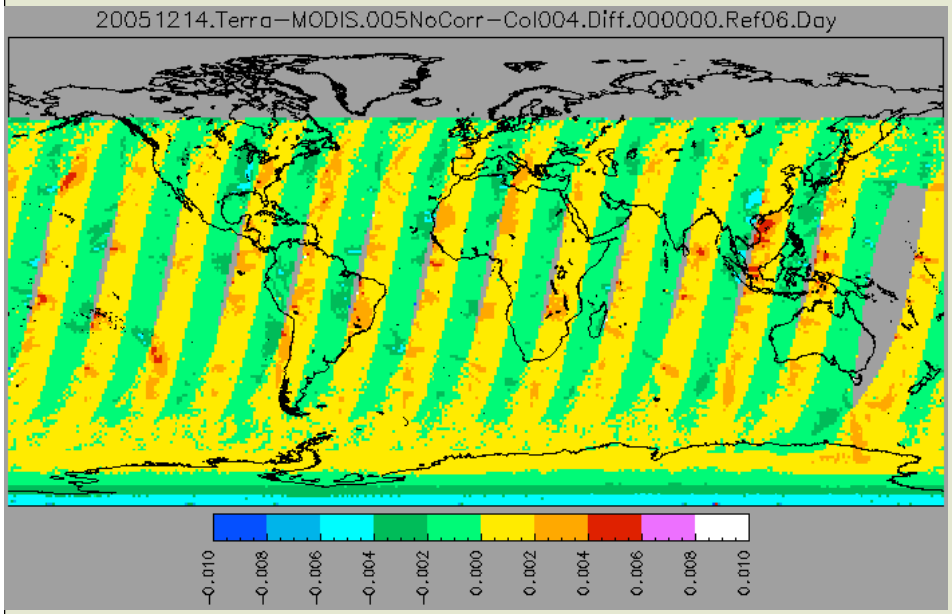


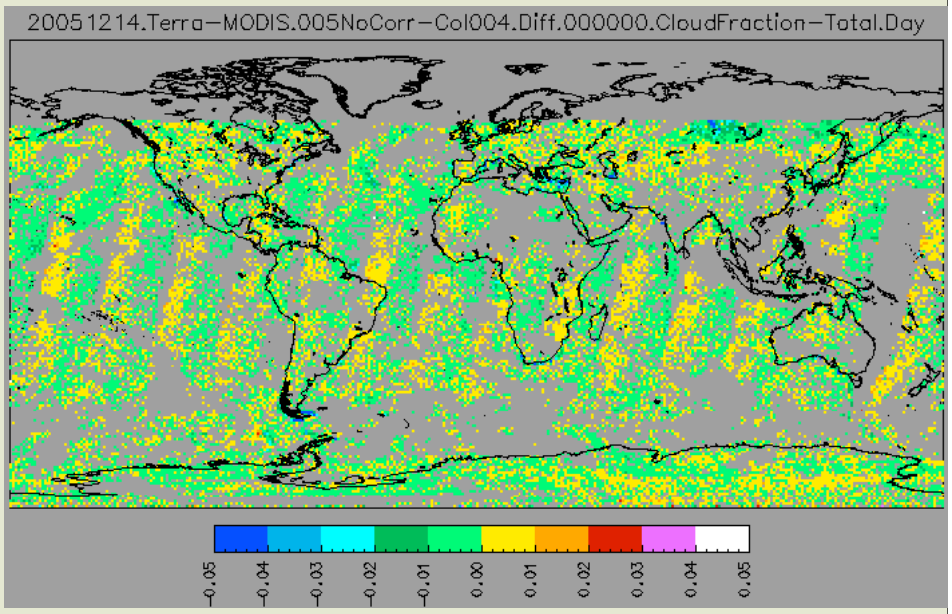
Cloud fraction



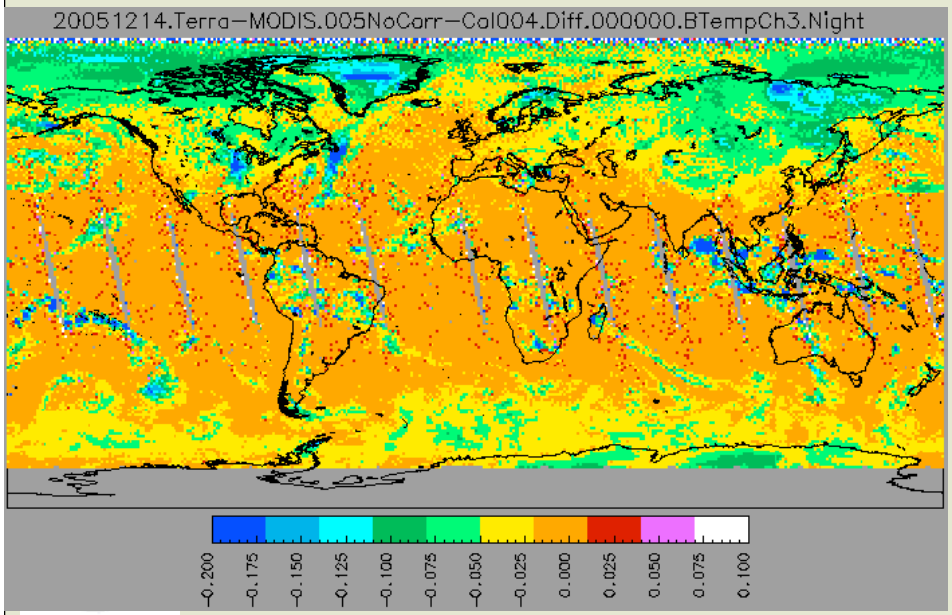
Impact of Collection 5 on Cloud Fraction 6/7/2005

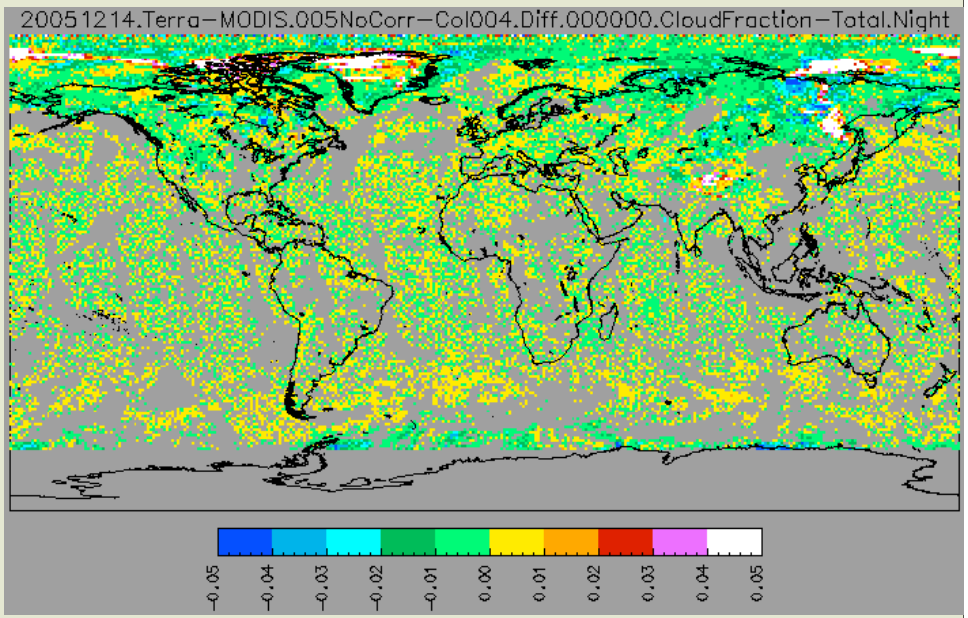
Ch 1 Ref Diff — DAY — Cloud fraction

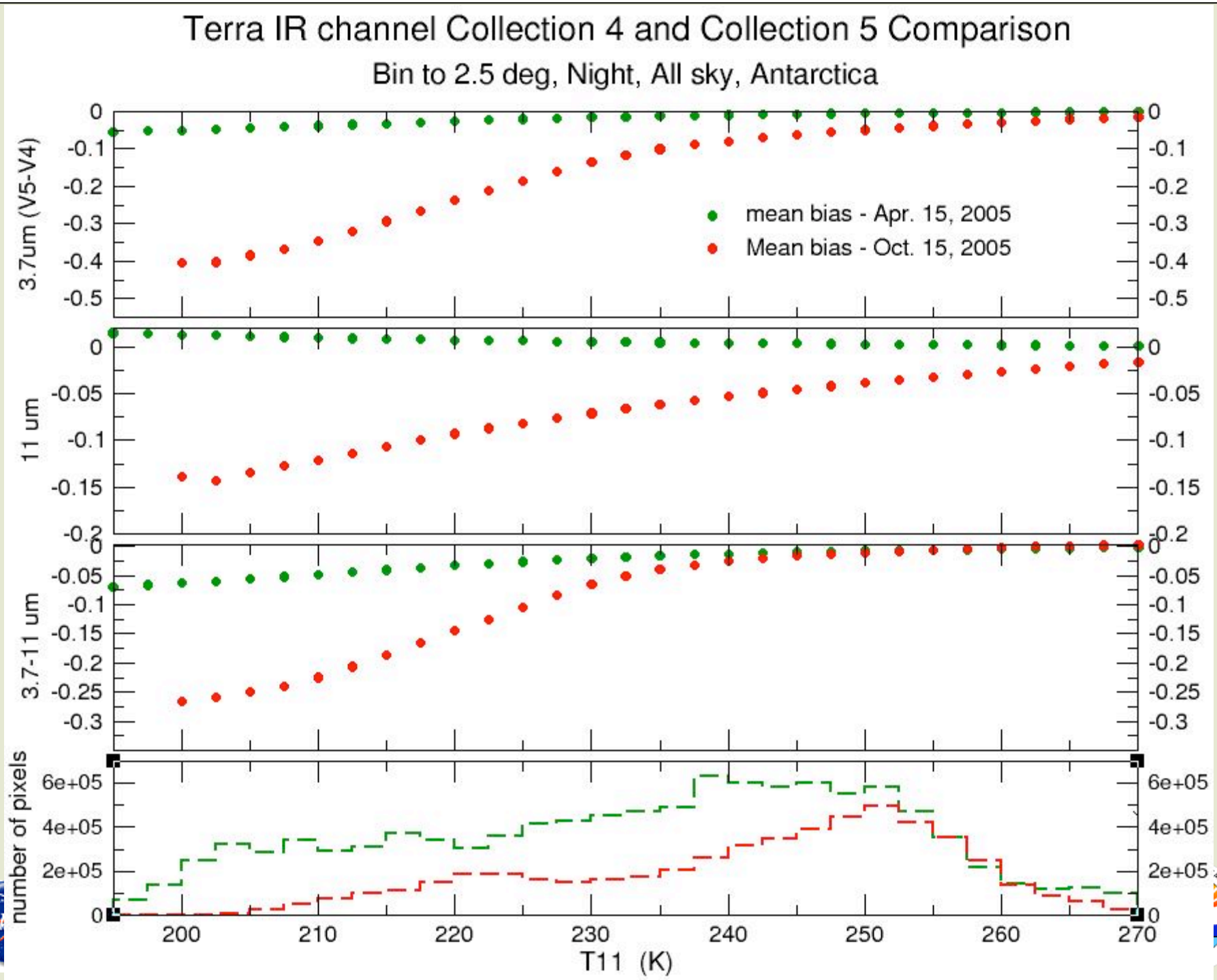




Ch 3 Temp Diff — NIGHT — Cloud fraction






Terra IR channel Collection 4 and Collection 5 Comparison
Bin to 2.5 deg, Night, All sky, Antarctica
3.7um (V5-V4)
mean bias - Apr. 15, 2005
Mean bias - Oct. 15, 2005
11 um
3.7-11 um
number of pixels
T11 (K)

Impact of Collection 5 on Cloud Fraction

Decision:

Do we work further on this to attempt to make a correction(s)?

- May retrieve better (more V004-like) results for some locations and times

- Will retrieve worse (less V004-like) results for many locations and times

- Most changes will occur in polar areas

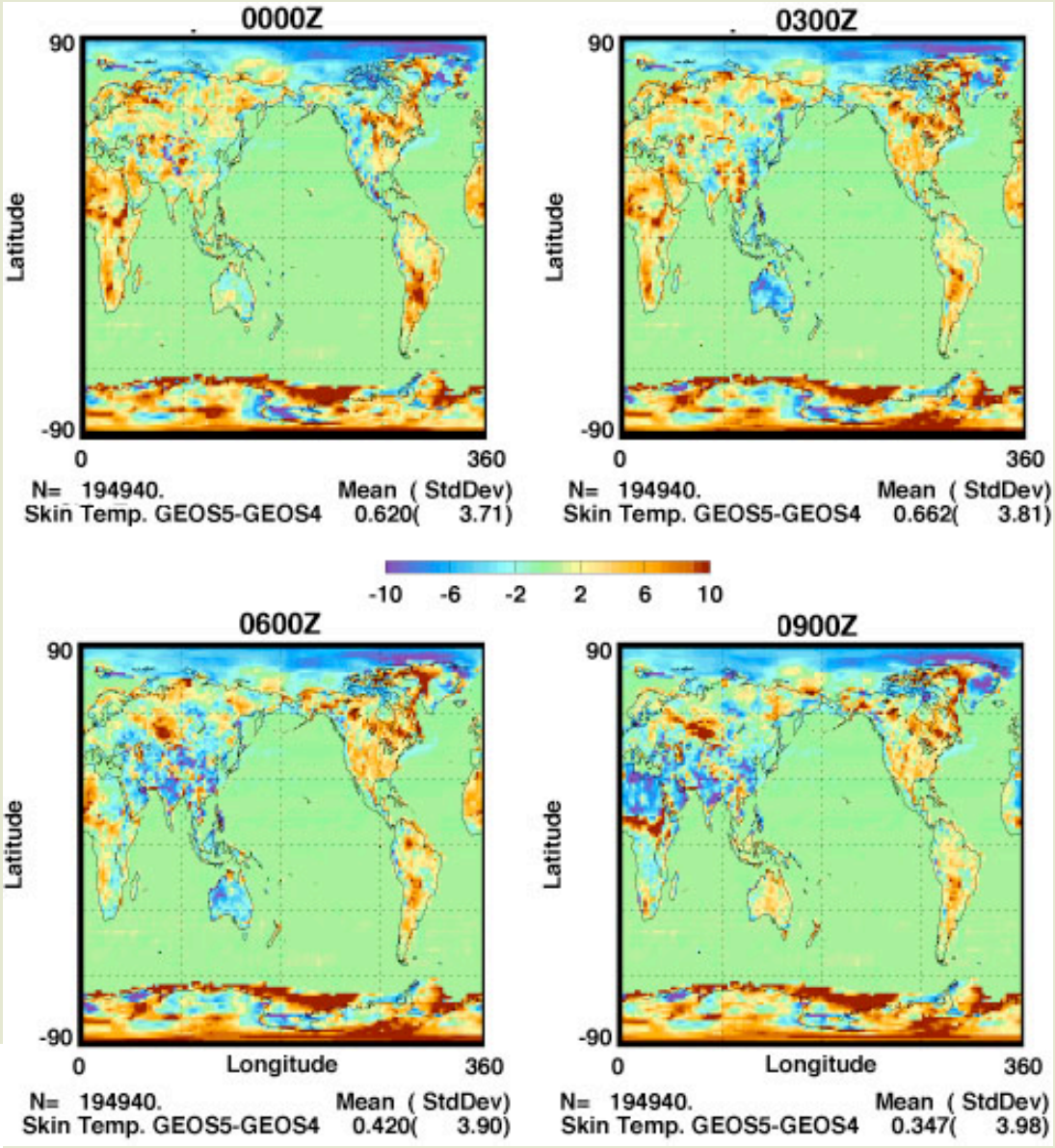
  - largest uncertainties already in polar regions

    => impact not particularly important

- Take V005 as is and run 2006-07 data?
- Check Aqua?

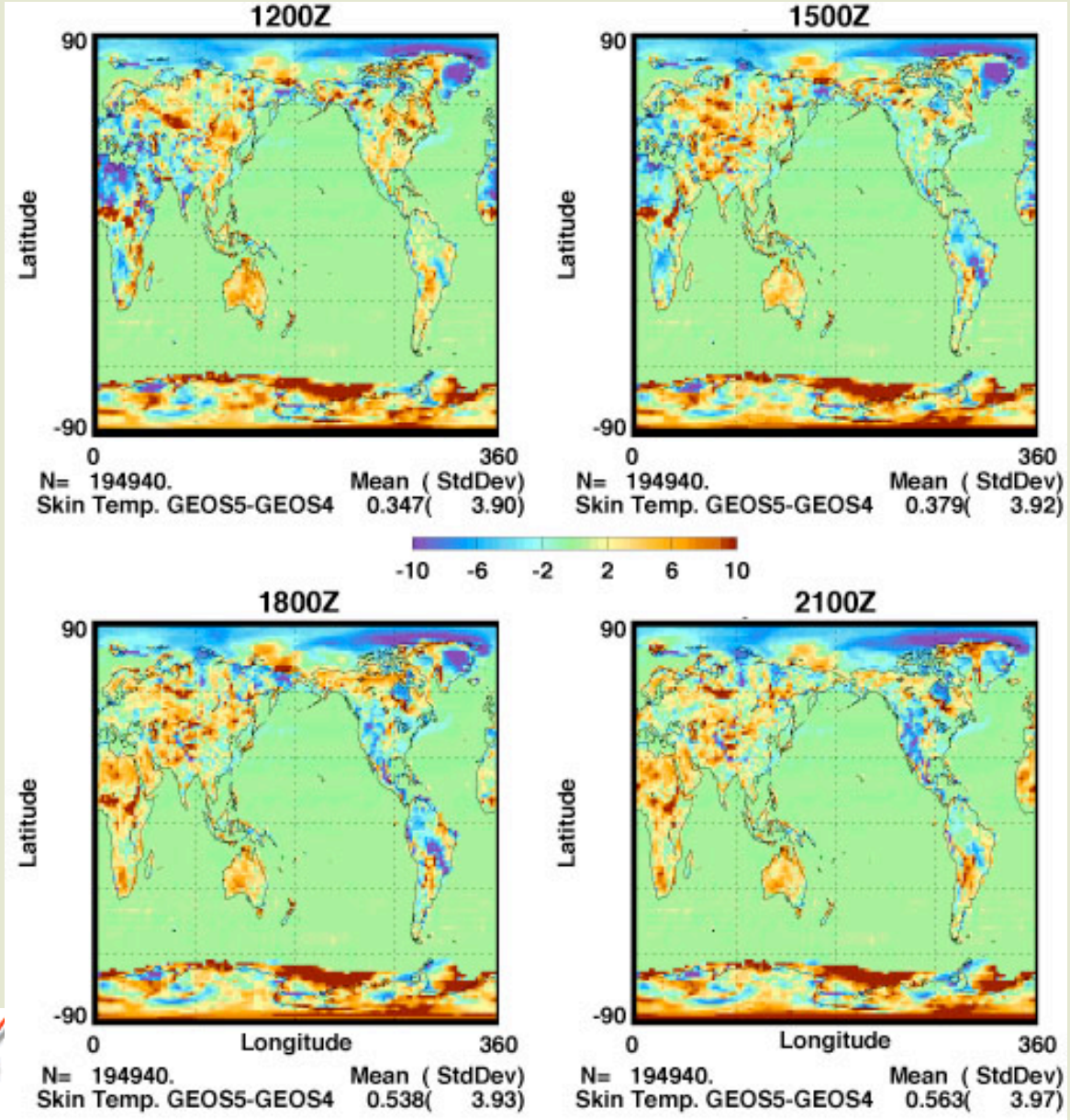
GEOS-4 vs MERRA

Skin Temperature Difference, GEOS5 - GEOS4, 15 April 2005, 0-9 Z



- *colder Arctic*
- *warmer Antarctic*
- *warmer nighttime land*
- *colder daytime land*

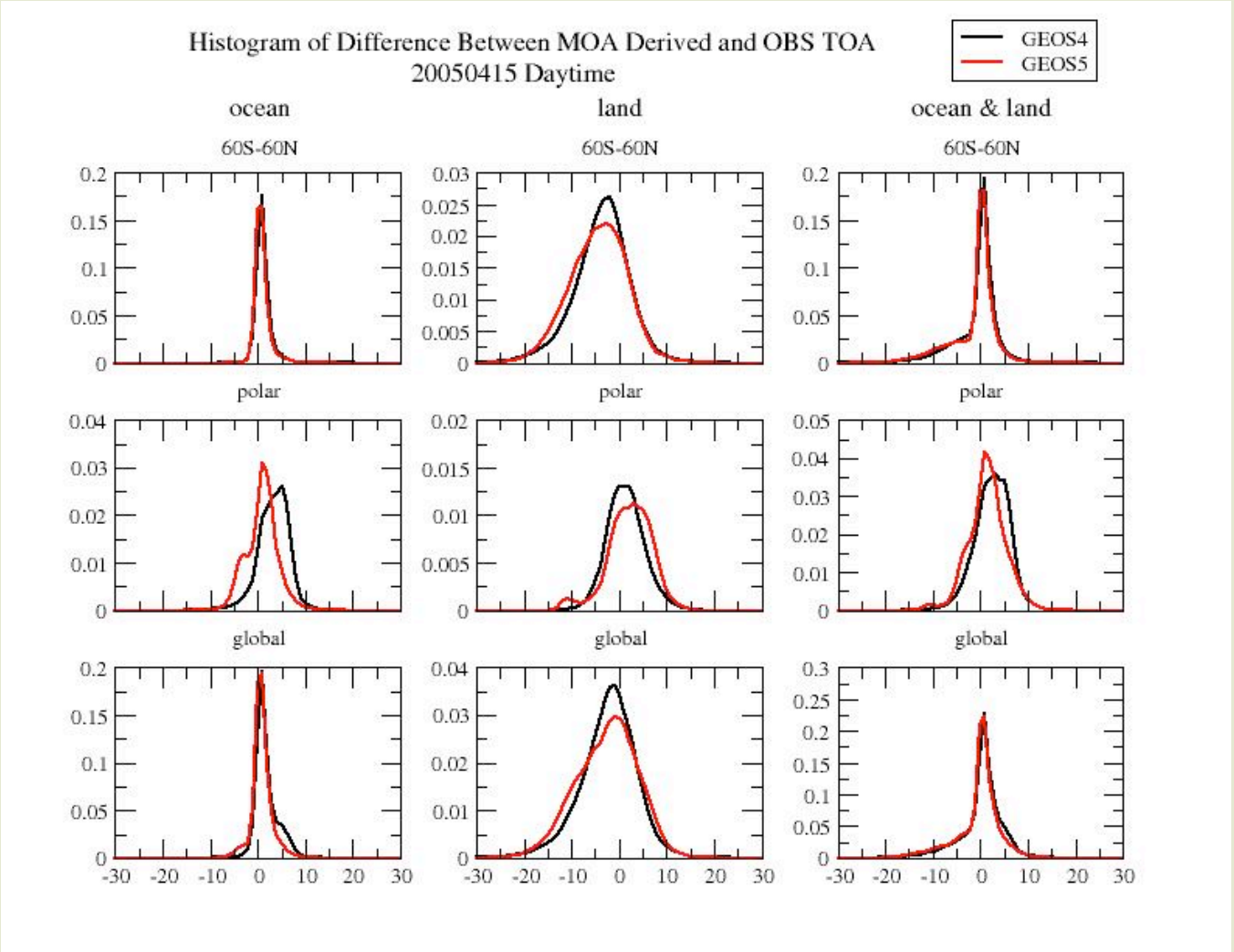
Skin Temperature Difference, GEOS5 - GEOS4, 15 April 2005, 12 -21 Z



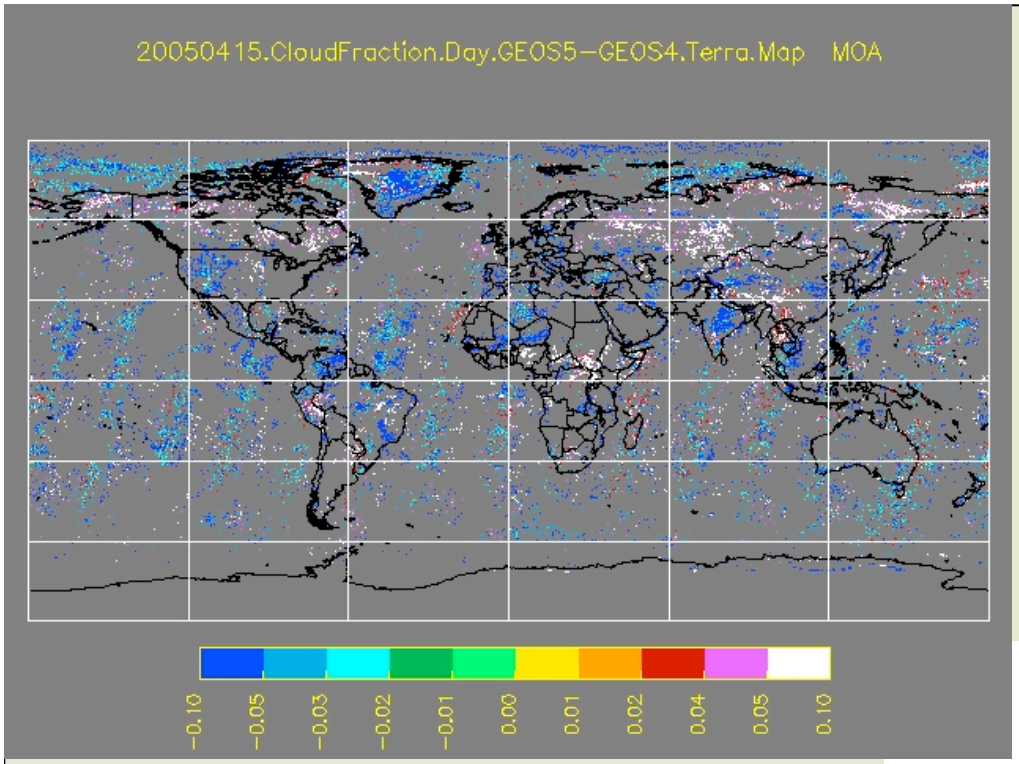
- *colder Arctic*
- *warmer Antarctic*
- *warmer nighttime land*
- *colder daytime land*

- *differences exceeding 10K not unusual*

Skin Temperature Difference, GEOS5 - GEOS4, 15 April 2005



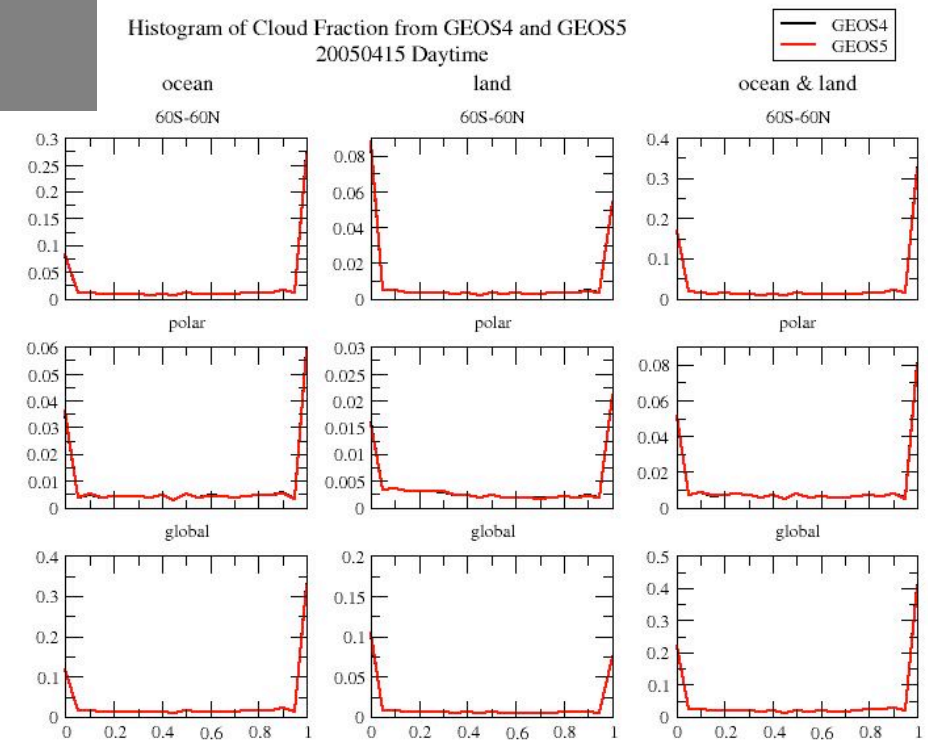
- *little difference over ocean compared to observations*
- *only slightly better agreement over land with GEOS4*

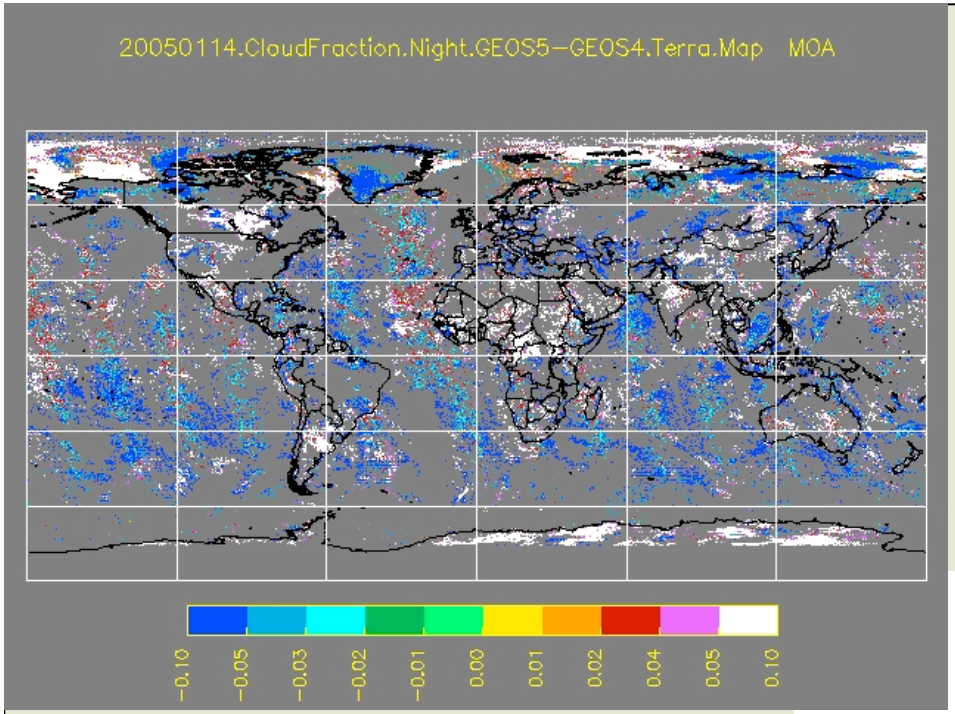


- *insignificant overall change in daytime cloud fraction*
- *more decrease than increase overall*

Cloud Amount changes, GEOS5 - GEOS4, 15 April 2005

DAYTIME

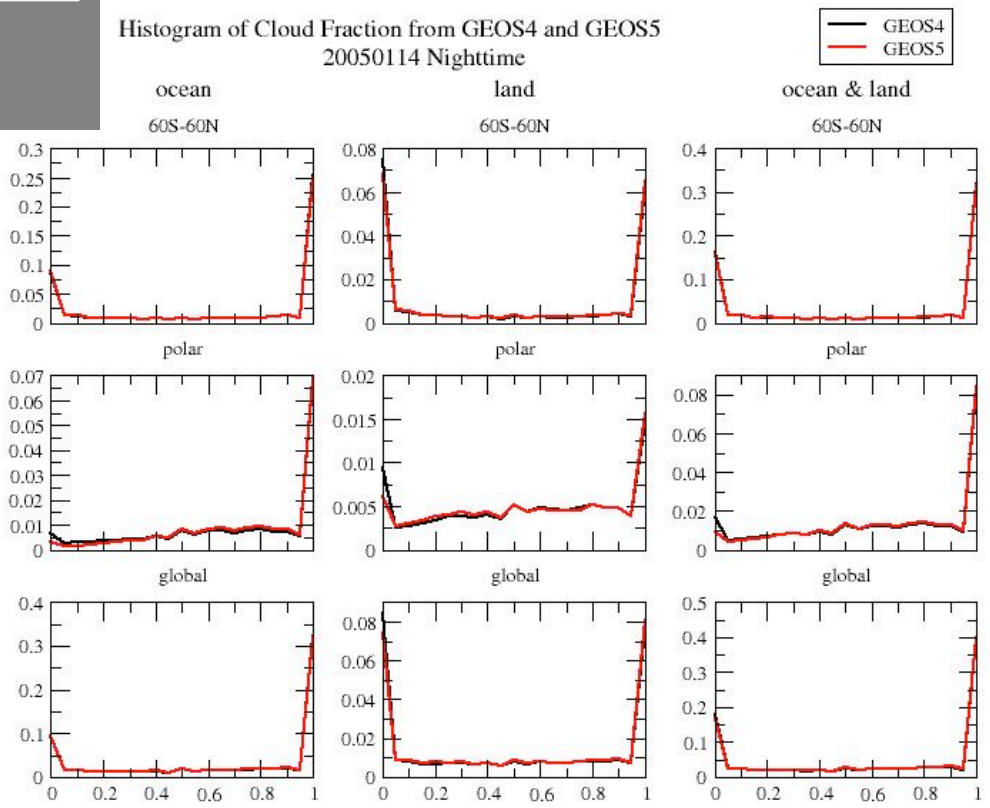




- *overall increase in nighttime cloud fraction*
- *greatest in polar regions*

Cloud Amount changes, GEOS5 - GEOS4, 15 April 2005

NIGHTTIME



GEOS-4 vs MERRA

- Initial runs made using GEOS-5
  - not any huge differences but some, especially in polar night
- Work mostly in vain since MERRA will be different from GEOS-5
  - have some idea what to expect
- MERRA studies still pending awaiting first actual MERRA data
  - examine whether changes require adjustments in cloud mask

Edition 3 Studies

- **Hi-res cloud detection and retrieval for low clouds (250-m into 1 km) -** now low priority

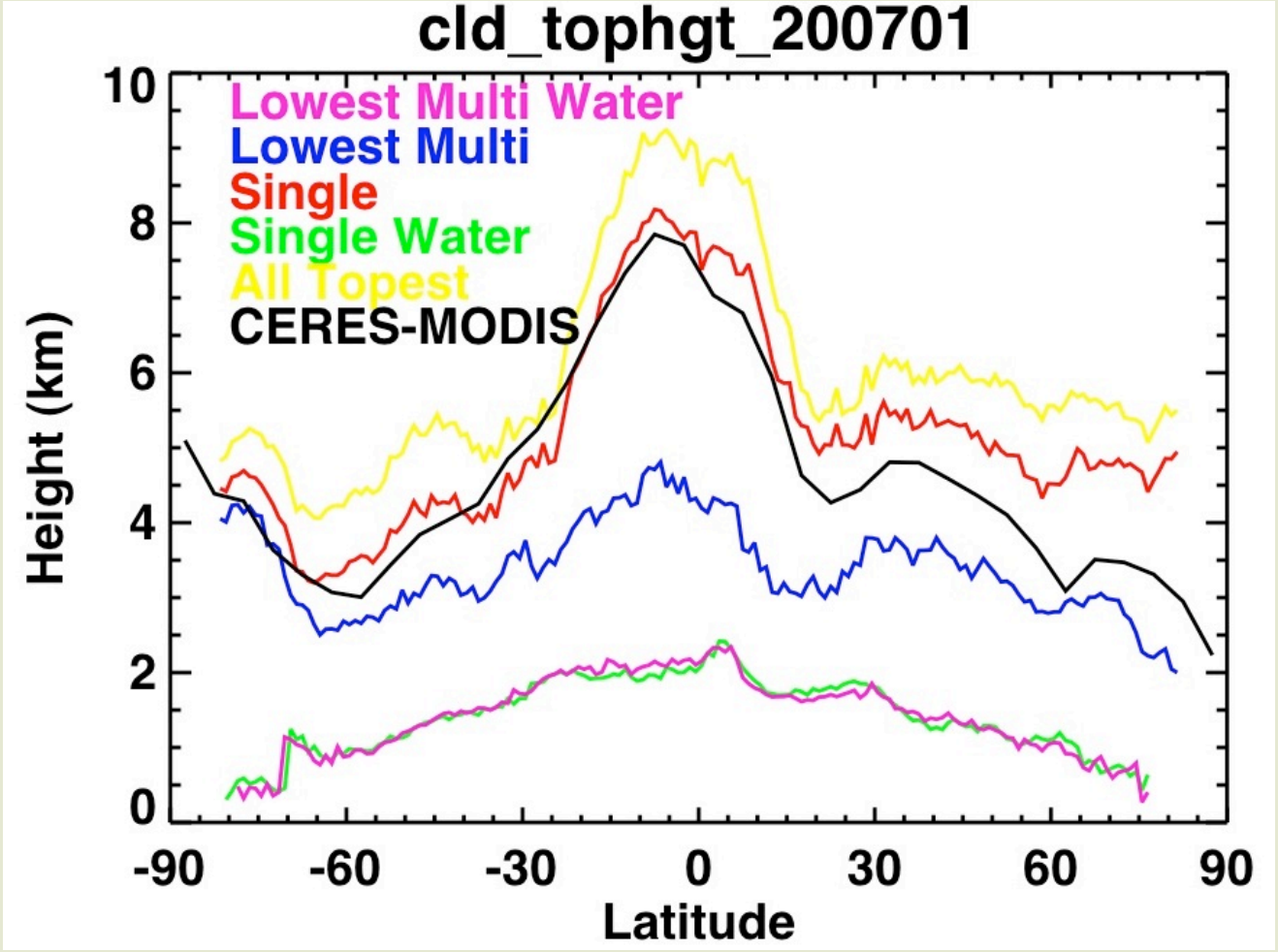
- **Multilayer cloud detection & retrieval -** Comparisons with CALIPSO

- **Cloud retrieval improvements**
  - adjustment to lapse rate method?
  - new ice cloud phase functions?
- **Cloud mask improvements**

- **Multispectral particle size retrievals**

- **Iterate on refinement, criteria for application**

CERES vs CALIPSO, Preliminary Results



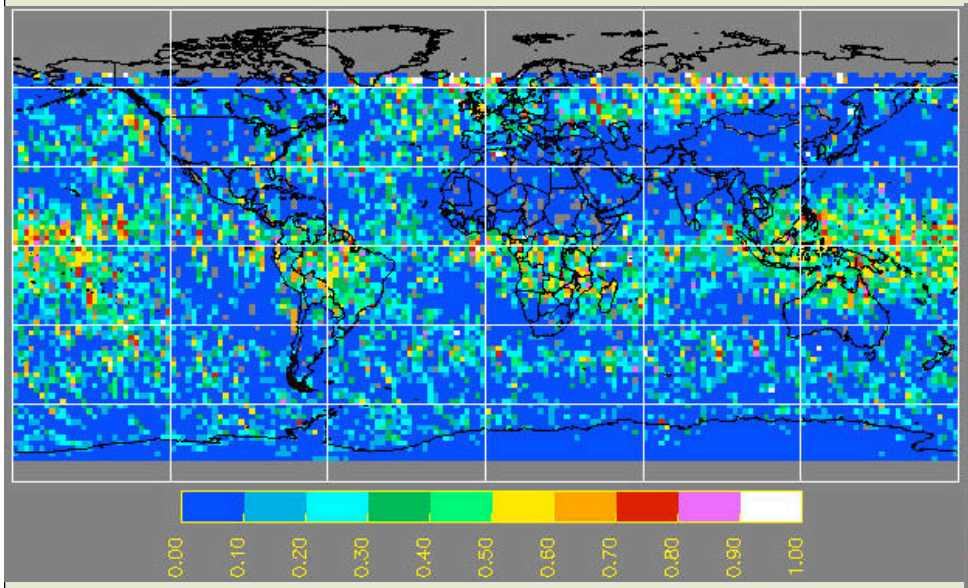
Sunny will discuss comparisons in more detail

Multilayer cloud detection and retrieval

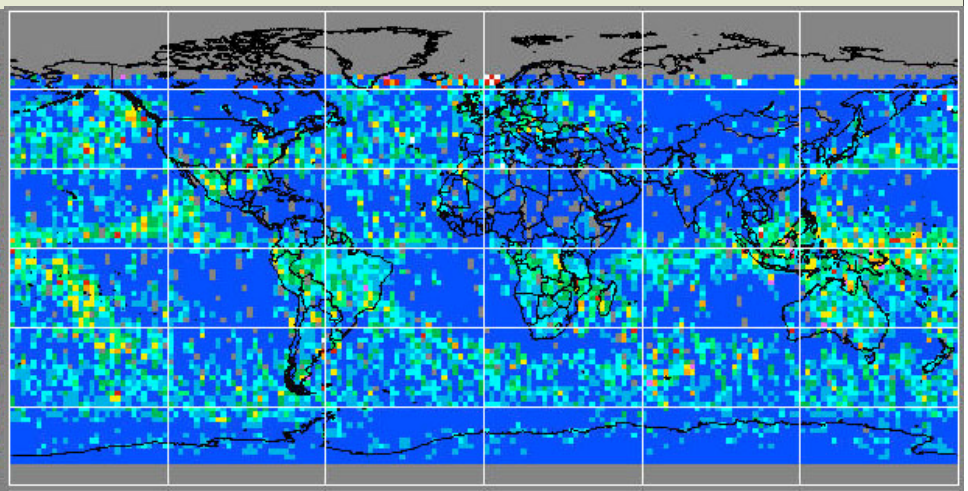
- Edition 3 prototype uses Chang & Li (2005) CO2-slicing/VISST & BTD overlapped cloud detection methods
  - only detects ML clouds when upper cloud $\tau < 4$
  - no snow surfaces
  - uses Chang & Li (2005) retrieval technique
- Mechanics of method currently operational & being tested
  - refinement is ongoing using CALIPSO
  - validation planned using same datasets
- Offline studies using MW & VISST (MCRS) over ocean for thicker clouds
  - complementary to CO2 method, but can be used to validate CO2 method for many conditions
  - 2 papers recently published using Aqua/AMSR-E, VIRS/TMI
  - proposal submitted to test combining MCRS/CO2 techniques

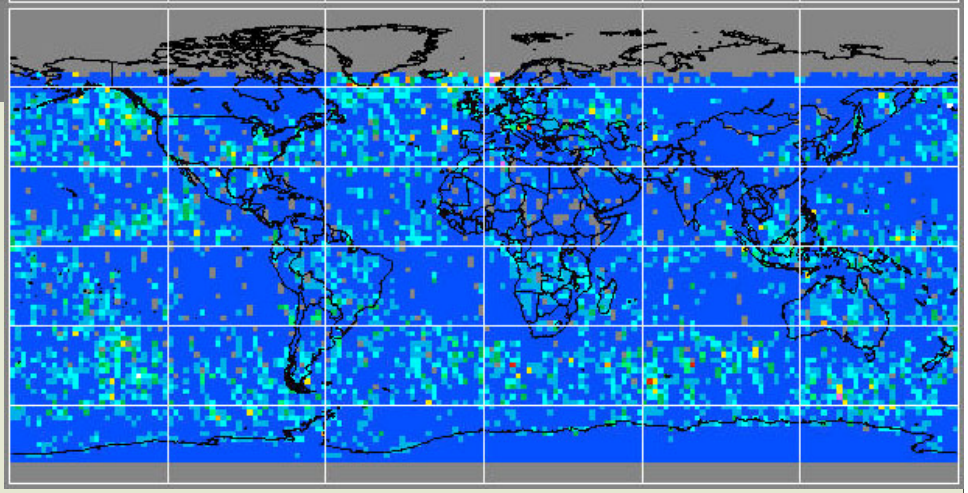
CALIPSO VS CO2 & BTD MULTI-LAYER DETECTION METHODS, 1/07

CALIPSO



BTD





CO2

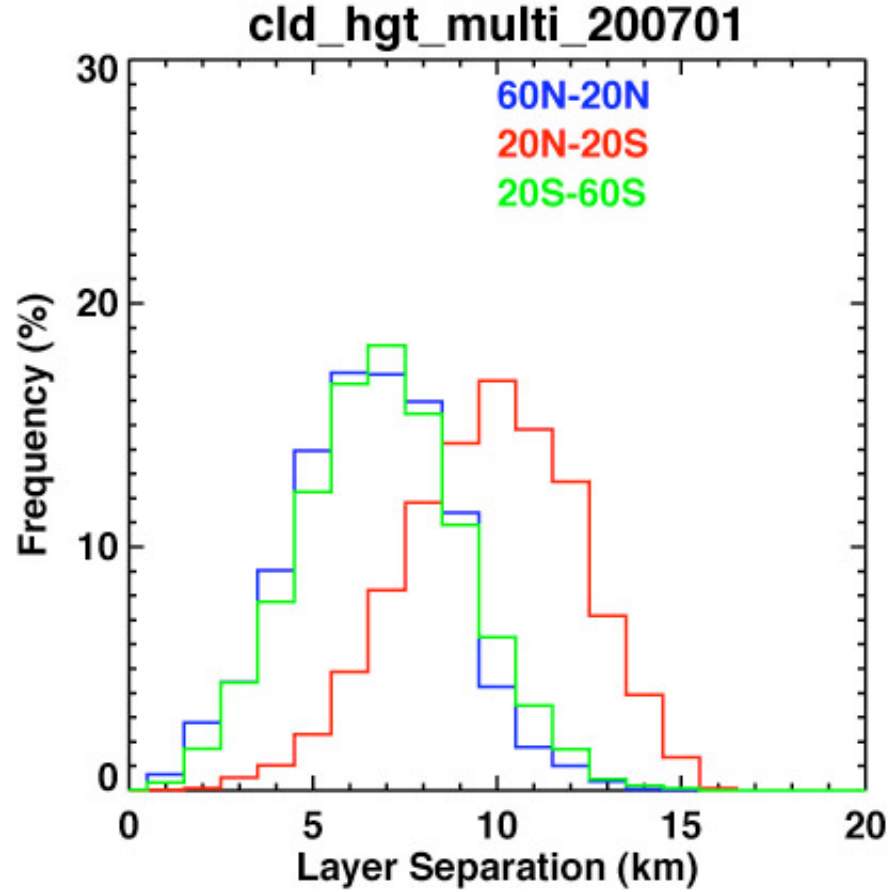
- CO2 detects ML clouds in correct are but not enough
- BTD detects more ML clouds
- Both miss edges of big systems,

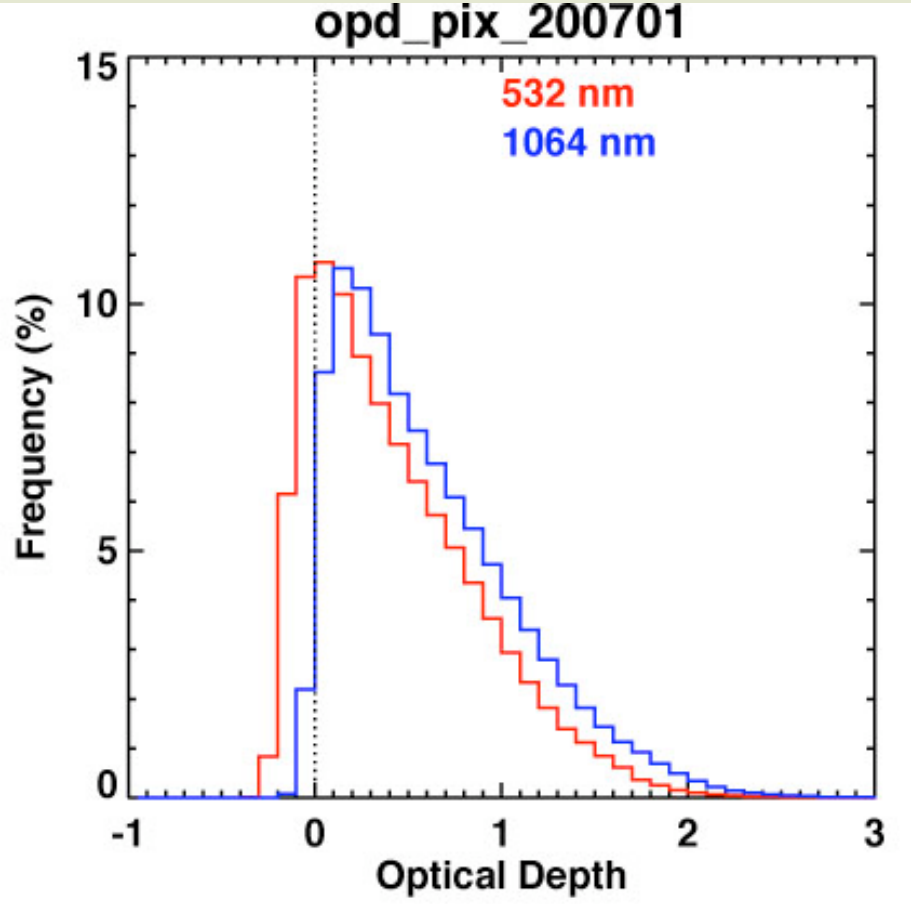
  e.g., ITCZ, thin cirrus?

- CO2 being refined
- one-to-one comparisons being used to revise techniques

2-Layer Cloud Separation & Upper Layer Optical Depths

CALIPSO, January 2007





- Average separation is 6.5 km in non-tropical areas
- 28% of UL clouds have tau < 0.1, 46% with tau < 0.3

Summary of Matched Data Results, January 2007

Separation > 6.5 km

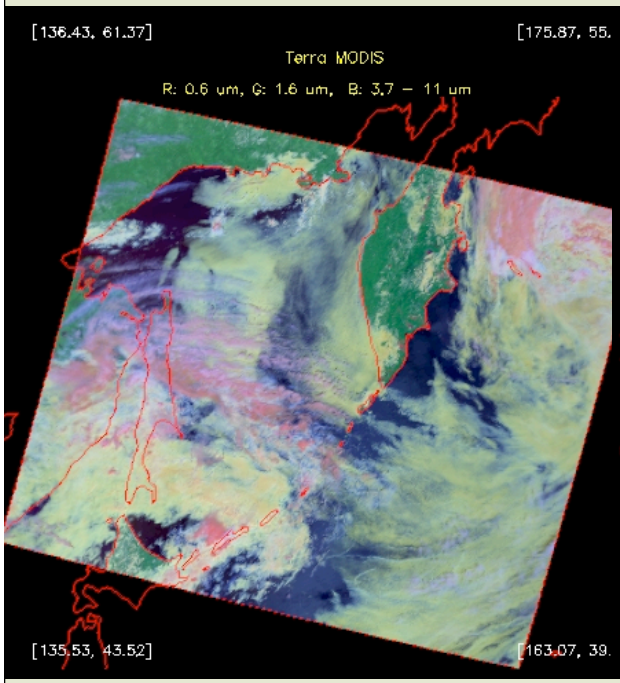
CALIPSO		ML		SL	
		BTD	CO2	BTD	CO2
NP Ocn	ML	0.29	0.23	0.70	0.77
	SL	0.13	0.06	0.87	0.94
NP Lnd	ML	0.29	0.20	0.71	0.80
	SL	0.13	0.05	0.87	0.95
Pol Ocn	ML	0.14	0.17	0.86	0.83
	SL	0.07	0.07	0.93	0.93
Pol Lnd	ML	0.08	0.06	0.92	0.94
	SL	0.04	0.03	0.96	0.98

- Only 25-30% of ML clouds detected
- CO2 has better false positive response

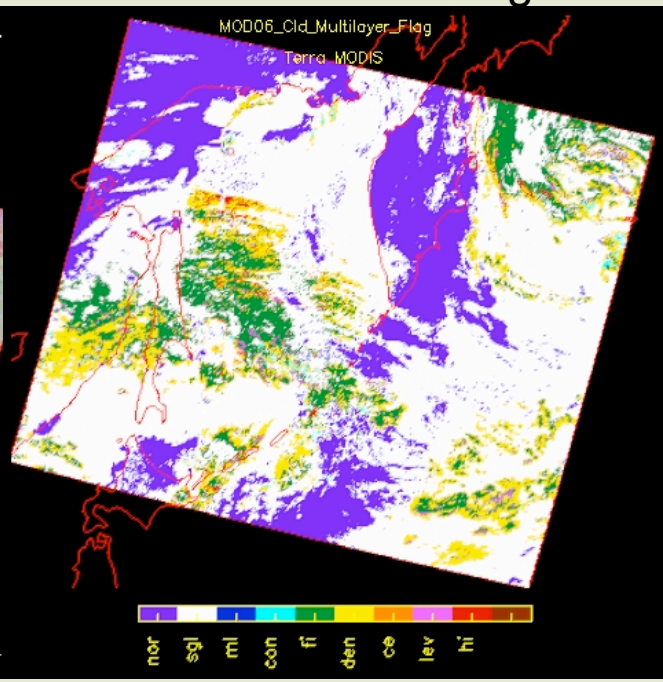
Multilayer Detection & Retrieval Future

- Use matched CALIPSO - MODIS data to refine & define what the ML clouds that are detected & those that are missed
- Combination of BTD & CO2 will be used to detect ML clouds
- Results similar to those from different methods used by MODIS

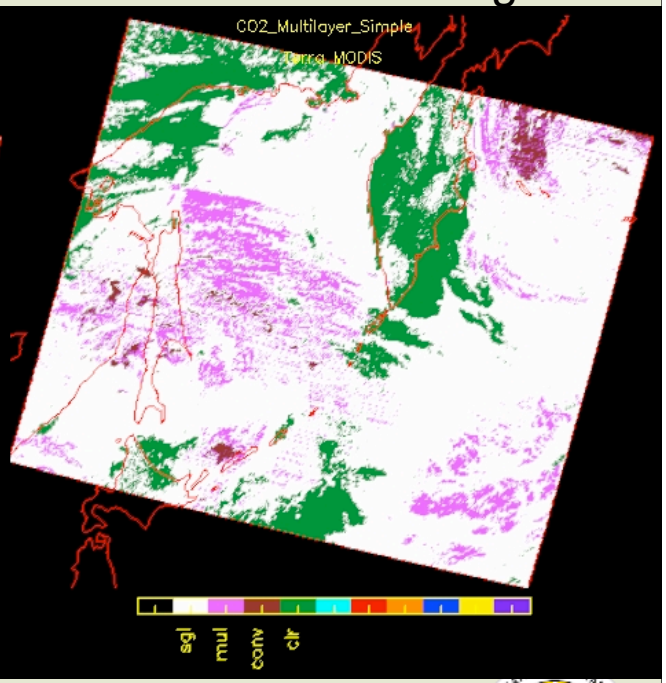
MODIS RGB



MOD06 ML Flag



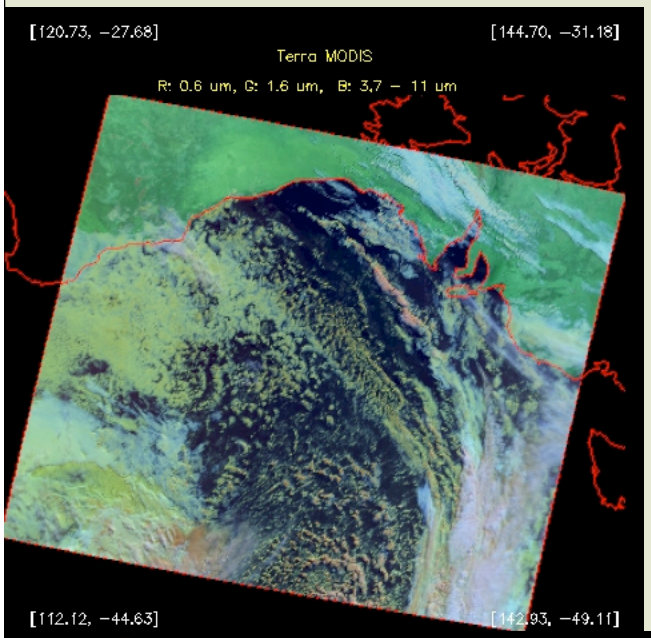
CO2 ML Flag



Multispectral particle size retrieval

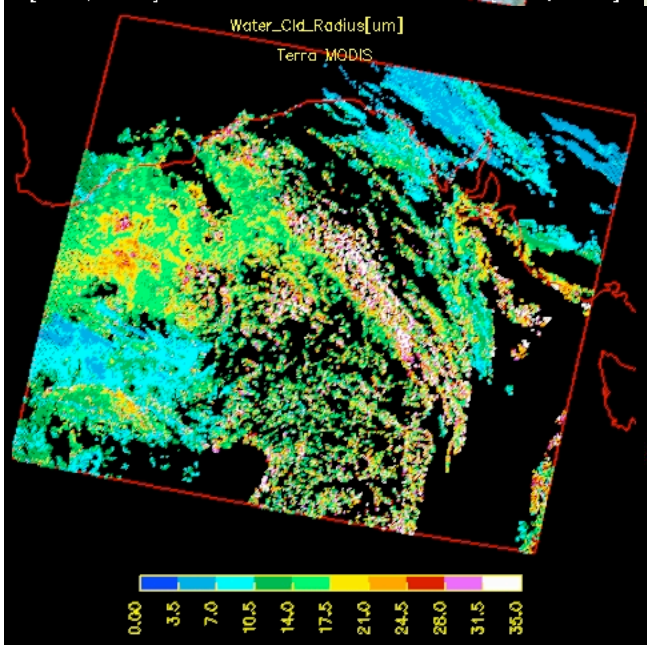
- Two wavelengths will be used to retrieve reff or Deff in Ed3 VISST
  - not over ice/snow
  - 1.6, 2.1, 3.8 μm
- Retrieval yields new size and τ, which will be added to SSF
- Results should give information about precipitation & cloud structure
- Better estimates of LWP/IWP are possible
- Possible feedback to alter phase

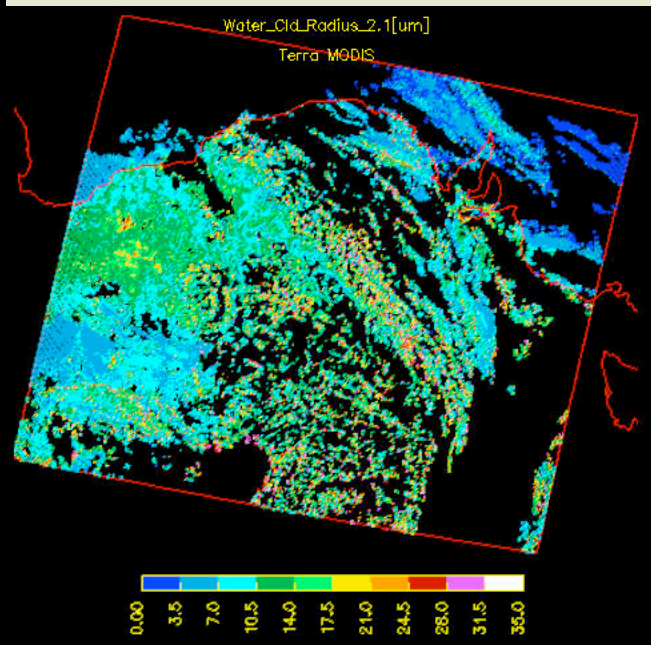
Multispectral Retrievals of Particle Size

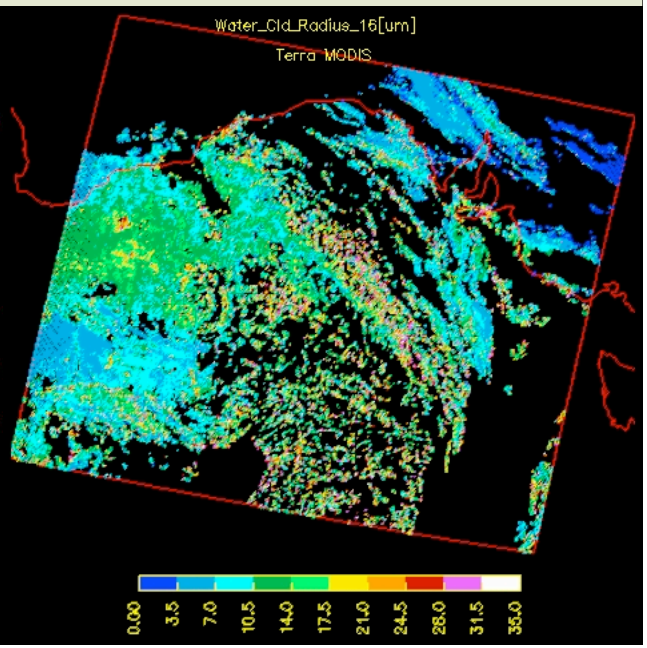


- Correct absorption values inserted for 2.1-μm retrievals
  - yields more reasonable values now

- **re(3.7) generally > re (1.6, 2.1)**

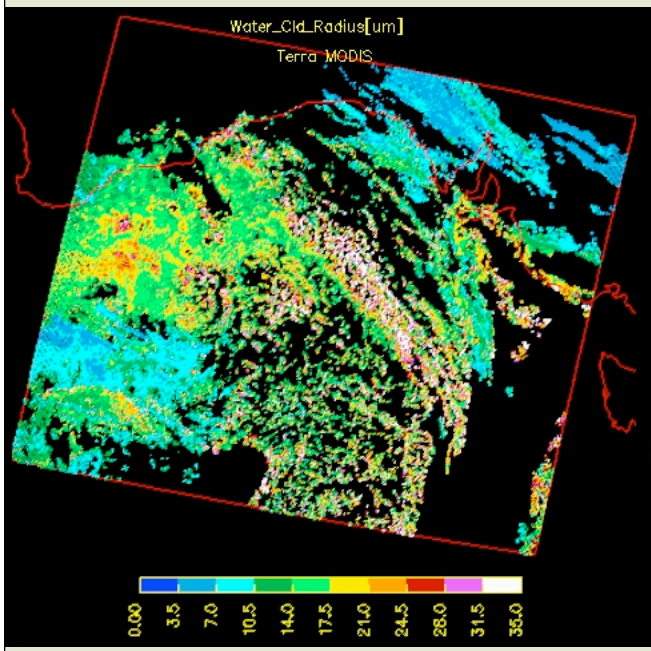




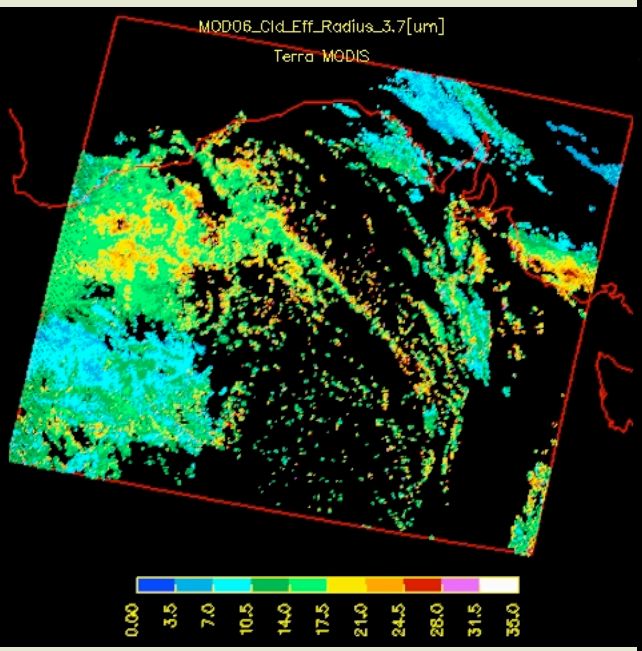


MOD06 Comparisons Now Routine

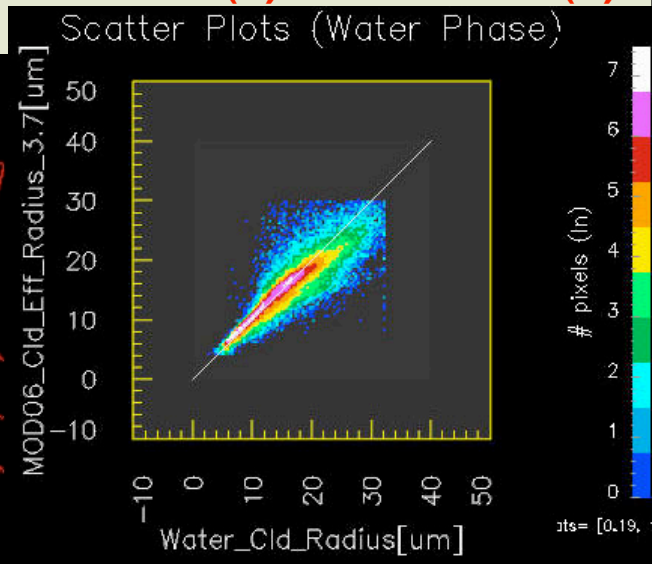
MOD06 re(3.7)

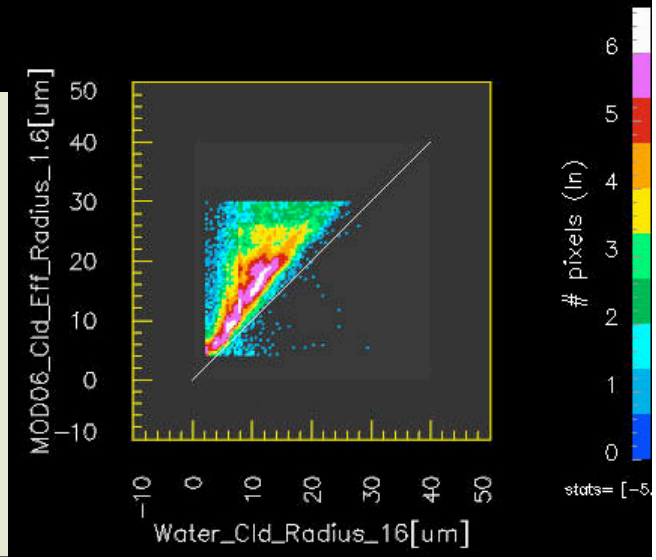


CERES re(3.7)



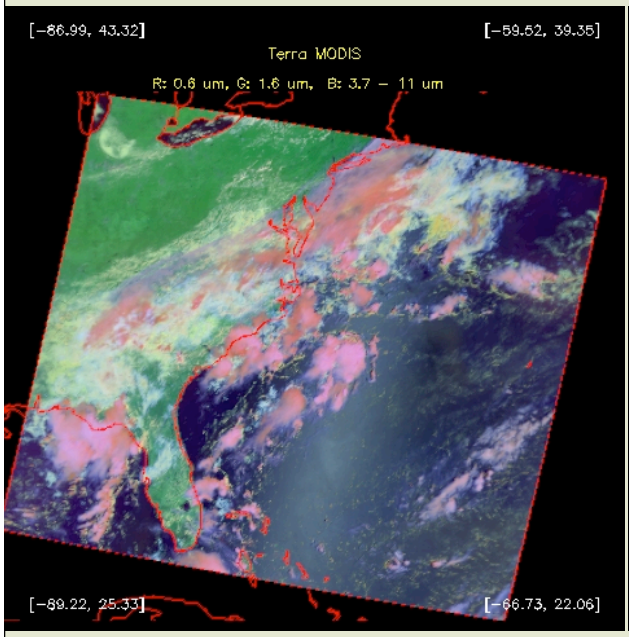
MOD06 re(λ) > CERES re(λ)

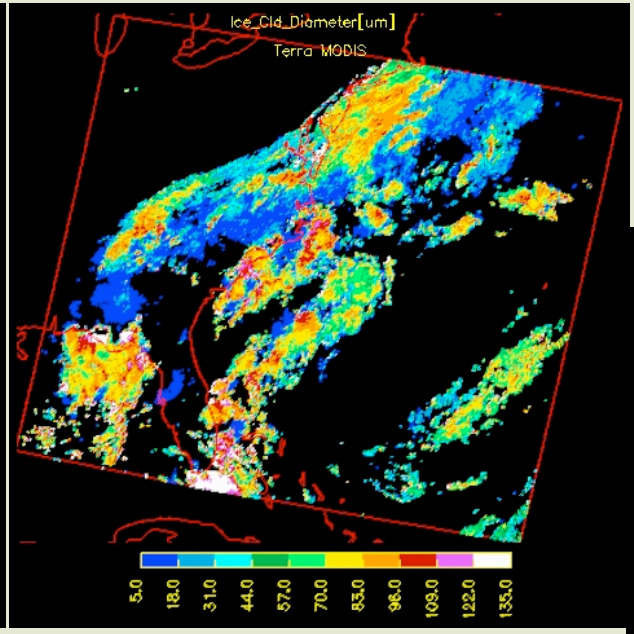


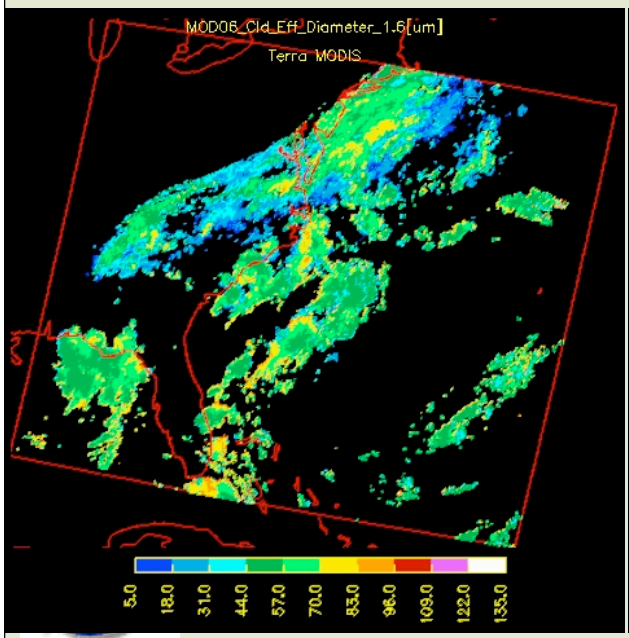


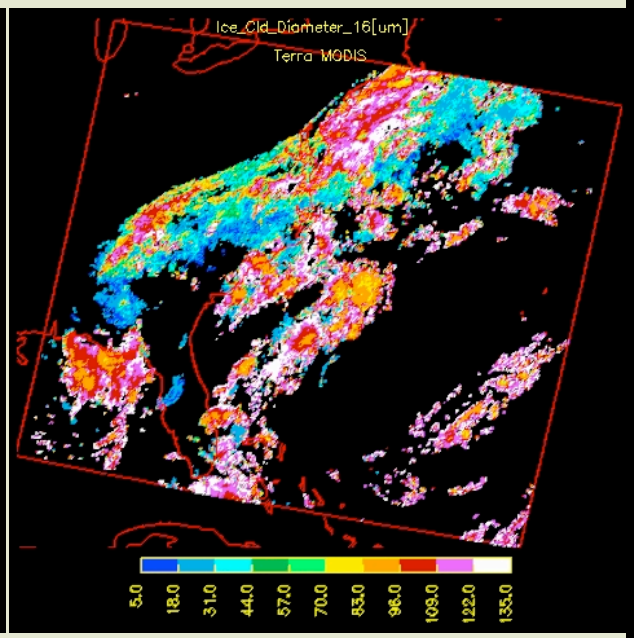
- MODIS retrieves larger values of re than CERES
- MODIS yields fewer retrievals altogether
- MODIS re(1.6) > re(3.7) generally

Multispectral Ice Diameter Retrievals

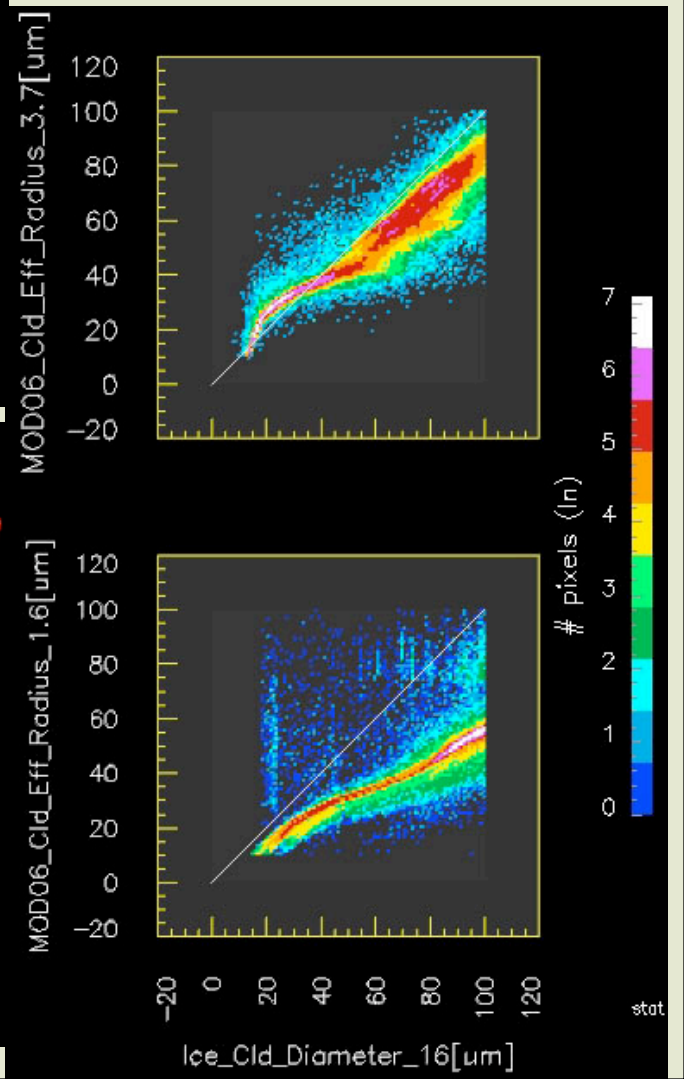




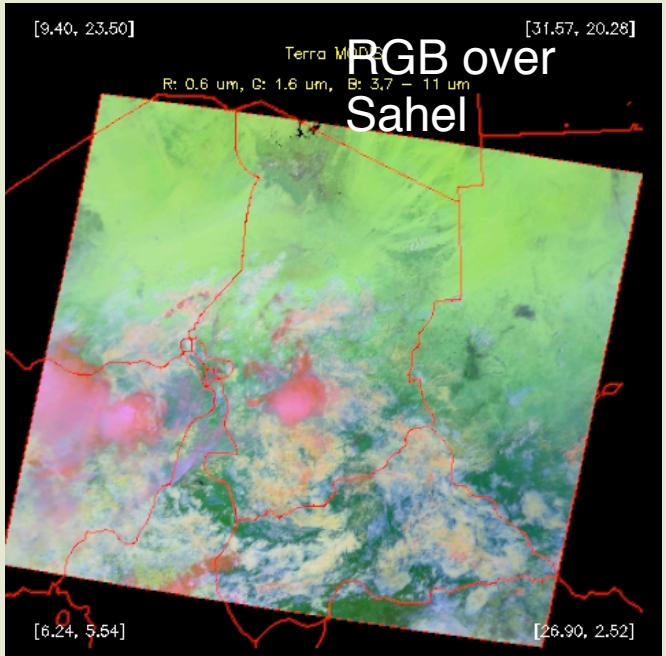


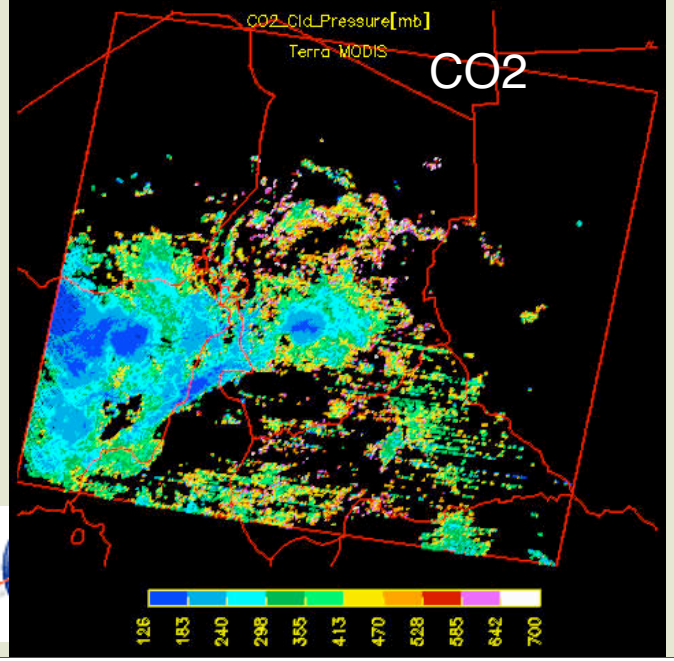


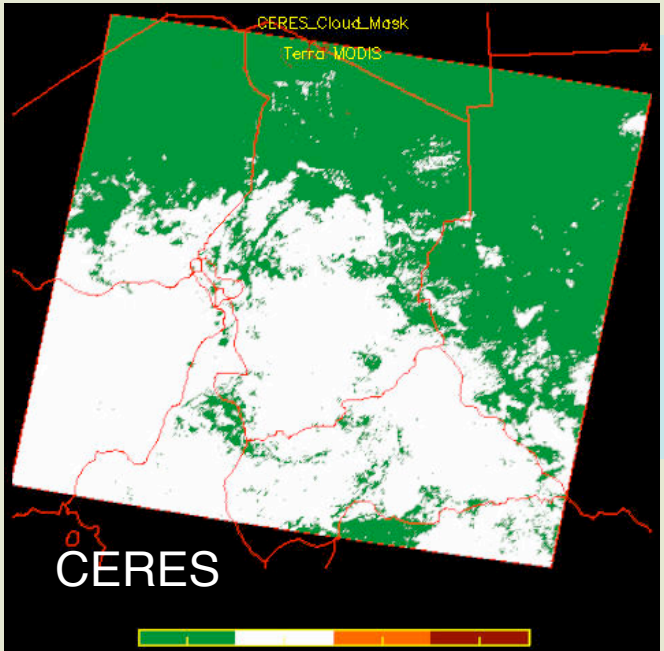
- MODIS retrieves less spectral variation in De than CERES - more work needed

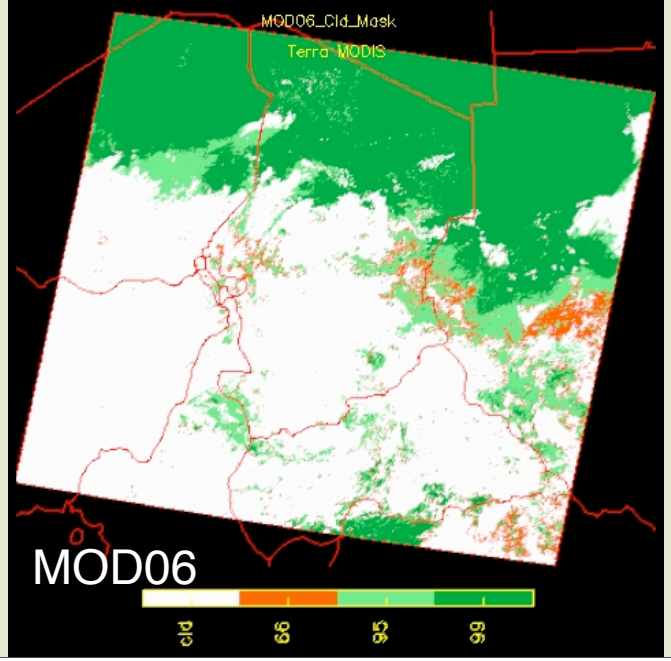


Use of CO2 for cloud mask under investigation







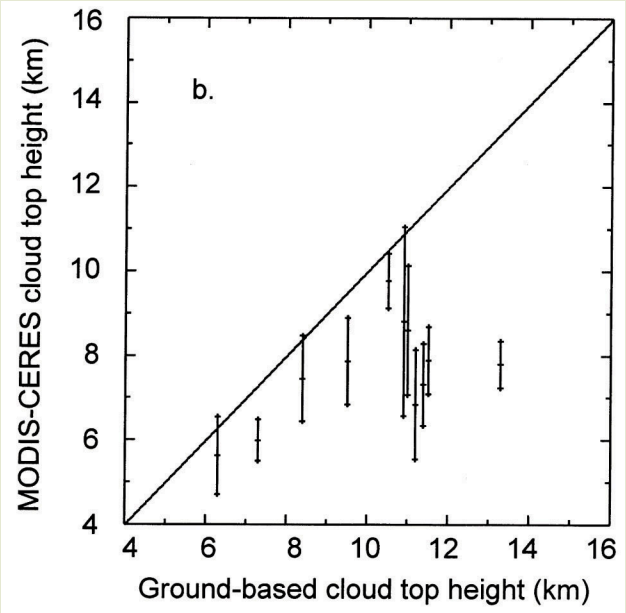


- MODIS mask picking up more clouds than CERES over some areas. Are these thin high clouds that can be seen with a CO2-slicing approach?

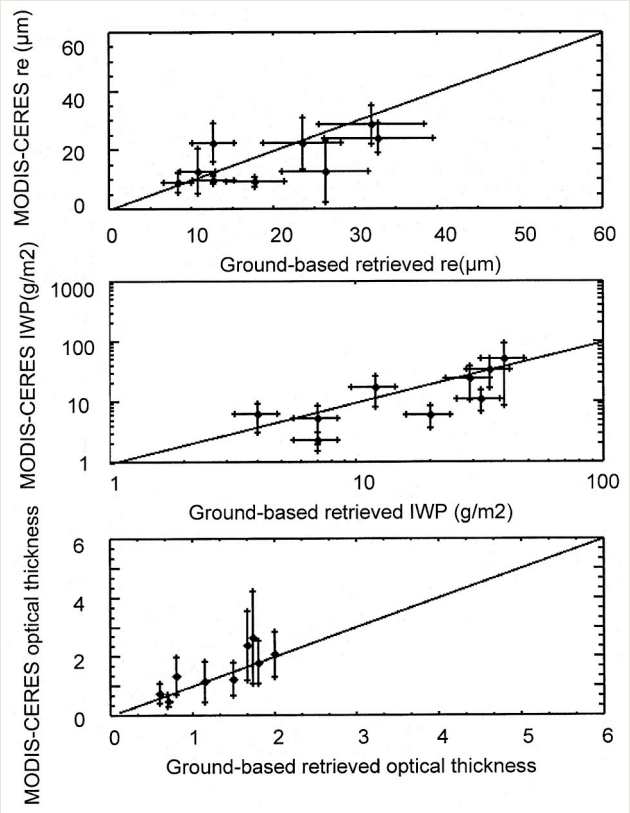
Changing Phase Functions for Ice

CERES cirrus clouds are too low, tau a little too large

De a little small, IWP looks good - what is problem



from Mace et al. (2005)



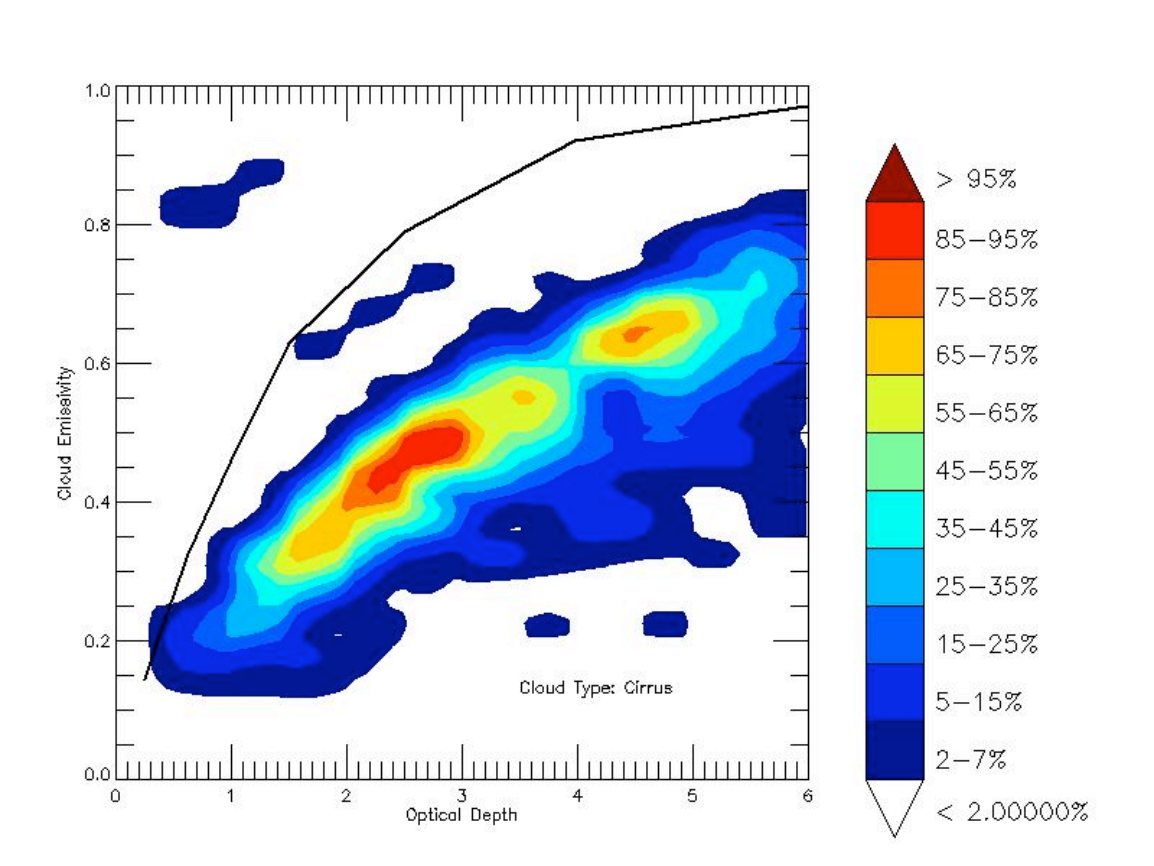
Maybe CERES phase functions are no good -

- MODIS uses “more realistic” ice models

MOD06 gets pretty good cirrus heights from CO2-slicing

- but tau is larger than CERES - inconsistent!

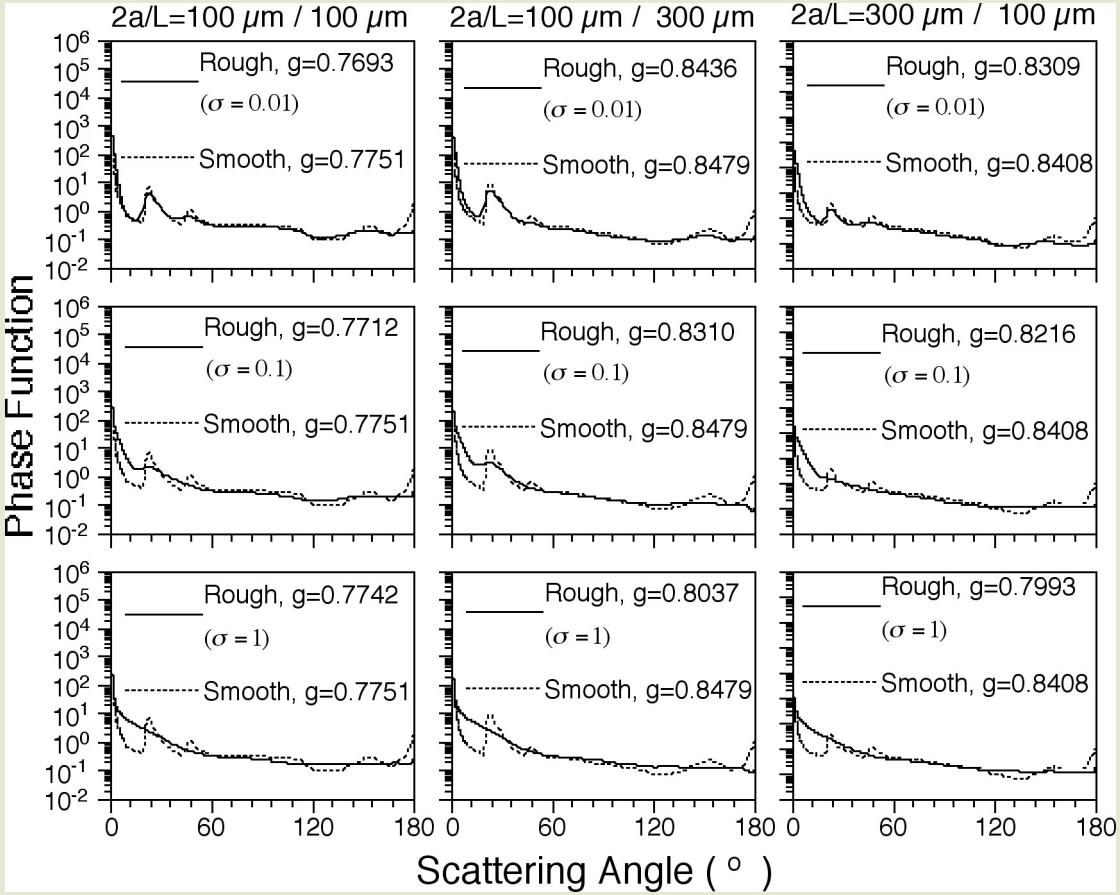
MOD06 CO2 cirrus emissivity vs VIS optical depth



How do we get better heights but same IWP?

Roughened Ice Crystals

- recent measurements indicate g < 0.8 in many cirrus clouds, down to 0.75
- roughened ice crystals decrease g for same size and shape
- measurements show crystals not always smooth



Yang et al. (2007) developed roughened ice crystal phase functions -

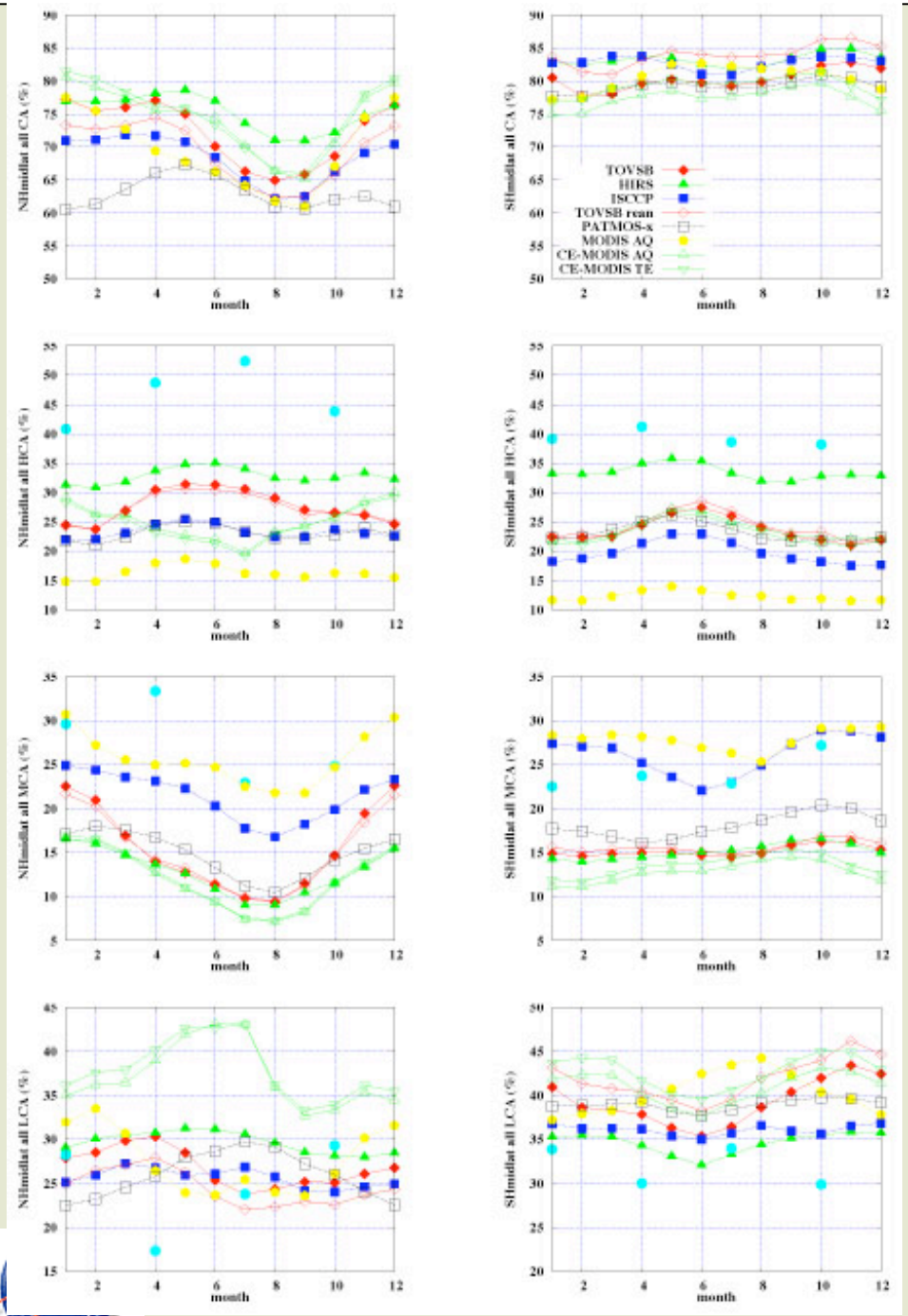
σ denotes roughness index

- Backscatter peak disappears
- halos reduced
- retrieved tau smaller
- De larger
- IWP nearly the same

* Testing to begin in May

OTHER ISSUES TO BE HANDLED IN ED3

- Smoother polar transition
- mixed phase clouds in Arctic (flag only)
- General mask/retrieval & calibration upgrades
  - fix lapse rate approach in midlevel inversion cases
- 1.6 vs 2.1 μm: 2.1 only for Terra SINT?
- Improved clear-sky
  - better updating of our maps
  - code changes in VIS parameterization
- Streamline code=> faster



Participation in GEWEX Cloud Comparisons for Climate

Mid-latitudes

- CERES on high end for NH, low end for SH in total cloud amount
- Different seasonal cycle in high clouds over NH
- Low end for NH & SH midlevel clouds
- High end for low clouds in NH & SH

CERES cloud-related papers published/accepted/submitted since last STM

1. Huang, J., P. Minnis, B. Lin, Y. Yi, T.-F. Fan, S. Sun-Mack, and J. K. Ayers, 2006: Determination of ice water path in ice-over-water cloud systems using combined MODIS and AMSR-E measurements. *Geophys. Res. Lett.*, **33**, L21801, 10.1029/2006GL027038.

2. Lin, B., B. A. Wielicki, P. Minnis, L. Chambers, K. Xu, Y. Hu, and A. Fan, 2006: The effect of environmental conditions on tropical deep convective systems observed from the TRMM satellite. *J. Climate*, **19**, 5745-5761.

3. Chepfer, H., P. Minnis, P. Dubuisson, M. Chiriaco, S. Sun-Mack, and E. D. Riviere, 2007: Nitric acid particles in cold thick ice clouds observed at global scale: Link with lightning, temperature, and upper tropospheric water vapor. *J. Geophys. Res.*, **112**, D05212, 10.1029/2005JD006602.

4. Verlinde, H., J. Y. Harrington, G. M. McFarquhar, V. T. Yannuzzi, A. Avramov, S. Greenberg, N. Johnson, G. Zhang, M. R. Poellot, J. H. Mather, D. D. Turner, E. W. Eloranta, B. D. Zak, A. J. Prenni, J. S. Daniel, G. L. Kok, D. C. Tobin, R. Holz, K. Sassen, D. Spangenberg, P. Minnis, T. P. Tooman, M. D. Ivey, S. J. Richarson, C. P. Bahrmann, P. J. DeMott, A. J. Heymsfield, and R. Scholfield, 2007:The Mixed-Phase Arctic Cloud Experiment (M-PACE). *Bull. Am. Meteorol. Soc.*, **88**, 205-221.

5. Minnis, P., J. Huang, B. Lin, Y. Yi, R. F. Arduini, T.-F. Fan, J. K. Ayers, and G. G. Mace, 2007: Ice cloud properties in ice-over-water cloud systems using TRMM VIRS and TMI data. *J. Geophys. Res.*, **112**, D06206, doi:10.1029/2006JD007626.

6. Chiriaco, M., et al., 2007: Comparison of CALIPSO-like, LaRC, and MODIS retrievals of ice cloud properties over SIRTA in France and Florida during CRYSTAL-FACE. In press, *J. Appl. Meteorol. Climatol.*

7. Lin, B., K. Xu, P. Minnis, B. A. Wielicki, Y. Hu, L. Chambers, A. Fan, and W. Sun, 2007: Coincident occurrences of tropical individula cirrus clouds and deep convective systems derived from TRMM observations. Submitted, *Geophys. Res. Lett.*

7 Papers submitted/ready related to CERES Clouds since last STM

8. Spangenberg, D. A., P. Minnis, M. D. Shupe, M. R. Poellot, and Z. Wang, 2006: Mixed-phase cloud detection over the Atmospheric Radiation Measurmeent North Slope of Alaska site from MODIS 6.7 - 12.0 μm data. Submitted to *J. Atmos. Oceanic Technol.*

9. Dong, X., P. Minnis, B. Xi, S. Sun-Mack, and Y. Chen, 2007: Comparison of CERES-MODIS stratus cloud properties with ground-based measurements at the DOE ARM Southern Great Plains site. Submitted, *J. Geophys. Res.*, 10.1029/2007JD008438.

10. Yang, P., G. W. Kattawar, G. Hong, P. Minnis, and Y. X. Hu, 2007: Uncertainties associated with the surface texture of ice particles in satellite-based retrieval of cirrus clouds: Part I. Single-scattering properties of ice crystals with surface roughness. *IEEE Trans. Geosci. Remote Sens.*, Submitted.

11. Yang, P., G. W. Kattawar, G. Hong, P. Minnis, and Y. X. Hu, 2007: Uncertainties associated with the surface texture of ice particles in satellite-based retrieval of cirrus clouds: Part II. Effect of particle surface roughness on retrieved cloud optical thickness and effective particle size. *IEEE Trans. Geosci. Remote Sens.*, Submitted.

12. Huang, J., P. Minnis, Y. Yi, Q. Tang, X. Wang, Y. Hu, Z. Liu, K. Ayers, C. Trepte, and D. Winker, 2007: Summer dust aerosols detected from CALIPSO observations over the Tibetan Plateau. *Geophys. Res. Lett.*, submitted.

13. Minnis, P., D. R. Doelling, L. Nguyen, and W. F. Miller, 2007: Intercalibration of the visible channels on the TRMM VIRS and MODIS on Terra and Aqua. Submitted, *J. Atmos. Oceanic Technol.*

CERES cloud-related papers in preparation

1. Minnis, P. , et al.: Cloud property retrievals for CERES.

2. Trepte, Q. Z., et al.: Cloud detection for CERES.

3. Sun-Mack, S. et al.: Clear-sky albedos determined from VIRS and MODIS data.

4. Minnis, P. et al., Comparisons of cloud amounts and heights from CERES-MODIS retrievals and GLAS data.

5. Minnis, P. et al., Intercalibration of MODIS and VIRS infrared and near-infrared channels.

6. Sun-Mack et al., Comparison of CERES and CALIPSO cloud amounts and heights.